instruction manual

RB-503

NORTH ATLANTIC
industries, inc.

ratio boxes

OPERATING AND INSTRUCTION MANUAL

MODEL RB-503 S-1068

RATIO BOX

CIRCUITS CONTAINED HEREIN
HAVE PATENTS APPLIED FOR:

NORTH ATLANTIC INDUSTRIES, INC.
Plainview New York

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200 terminal drive, plainview, n. y. OVerbrook 1-8600

TABLE OF CONTENTS

I.	General Description and Specifications	1.1
	General Description	1.1
	Specifications	1.3
II.	Installation	2.1
III.	Theory of Operation	3.1
	Schematic	3.2
IV.	Operating Procedure	4.1
	Terminals	4.1
	Switches	4.2
V.	Maintenance	5.1
	Calibration and Test Procedure	5.1
	Replacement Parts List	5.3
	Figure 5.1 - Test Setup	5.4

SECTION I

GENERAL DESCRIPTION AND SPECIFICATIONS

General Description

The North Atlantic Model RB-503 Ratio Box is a precision inductive voltage divider. It utilizes the latest advances in transformer engineering and provides high ratio accuracy, readability, and reliability. Typical design features are high input impedance, low series output impedance, and excellent phase characteristics, which enable this instrument to be used in a wide range of test applications.

The North Atlantic Model RB-503 has been designed for either bench or rack-mounted service, and it occupies a minimum panel space while providing excellent readability on in-line window dials.

This model features 6 digit readout utilizing 5 switched decades with switching transient suppression, and a single turn potentiometer.

Applications of this instrument are included in the

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instrumentation bulletin contained herein. A more detailed treatise on applications is contained in the appended "Application Notes for 200 Series Phase Angle Voltmeters."

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Specifications

Ratio Range:	0.000000 to +1.111110
Accuracy @ 400 cps (terminal linearity):	10 ppm
Frequency Range (within accuracy):	50 cps to 5kc
Frequency Range (useful):	50 cps to 10kc
Nominal Input Impedance @ 400 cps:	300K
Maximum Input Voltage:	.35f volts (f in cps) (not to exceed 350V)
Maximum DC Input:	Do not apply DC to input.
Nominal Output Resistance (peaks at ratio of .611110 approx, 0 at ratios of .0 and 1.0):	2.75 ohms
Phase Shift:	Less than 1 minute
Resolution:	5 decades plus 1 turn potentiometer
Switches:	Heavy duty
Size:	3-1/2"H x 19"W x 8"D 21 lbs.

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SECTION II

INSTALLATION

The North Atlantic Model RB-503 Ratio Box has been designed for either bench or rack-mounted service. Fold away legs and end plates are provided to facilitate use on the bench. The end plates are easily removed to allow quick conversion for rack mounting. The panel space required for the instrument is 3-1/2"Hx 19"W.

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SECTION III

THEORY OF OPERATION

The North Atlantic Model RB-503 consists of 5 decades of inductive dividers with tap selection provided by heavy duty, high reliability, rotary switches. Transient suppression is provided on the switches to allow maximum usability in nulling circuits. A one-turn wirewound potentiometer is used in the 6th decade. The excitation for this potentiometer is provided by a winding having precisely 1/10th the voltage that excites the 3rd decade. The potentiometer voltage is again stepped down 100:1 to provide a 0-10ppm range.

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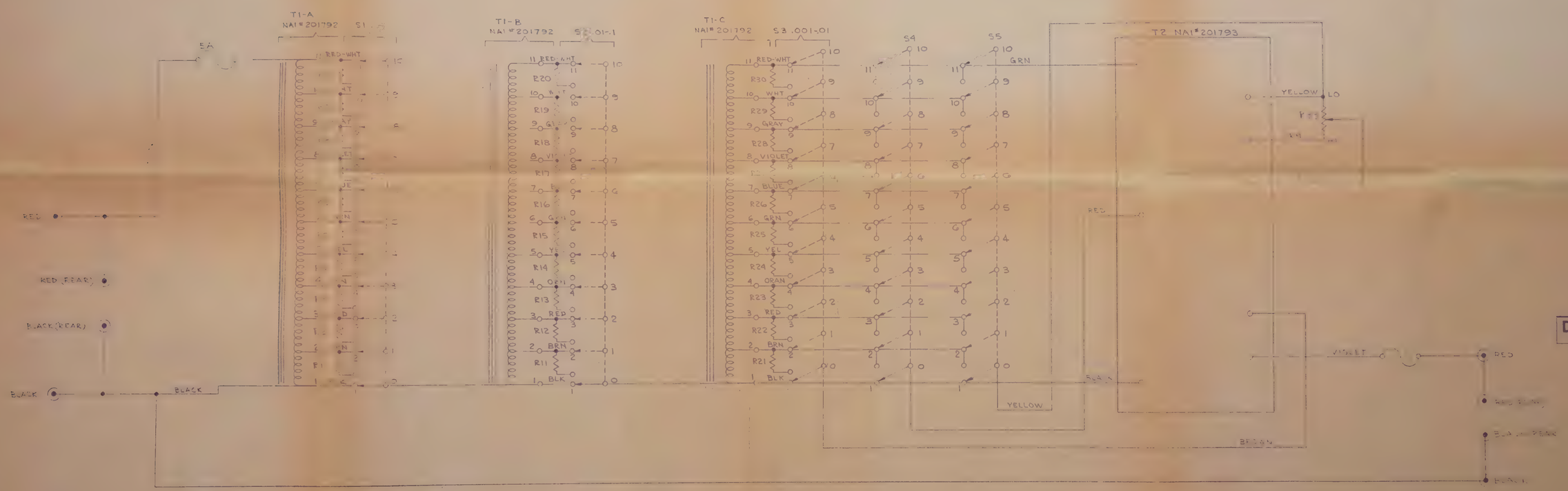
REVISIONS



D-760234

ITEM	PART NUMBER	DESCRIPTION	REQ
MATERIAL SPEC			
HEAT TREATMENT SPEC			
FINISH SPEC			

NORTH ATLANTIC industries, inc

DRAWN BY	DATE 3-24-82
CHECKED	CRAFT APP.
	ENG APP.
SCALE	TOLERANCES UNLESS OTHERWISE SPECIFIED: FRACT ± DEC ± ANG ±

TITLE: SCHEMATIC RATIO BOX KB-503C

D-760234

SHEET 1 OF 1

SECTION IV

OPERATING PROCEDURE

Terminals

The input excitation to be applied to the RB-503 should be connected to the "IN" and "COM" terminals located on the front of the device. The high potential should be connected to the "IN" terminal and ground reference should be connected to the "COM" terminal. A terminal is also provided for case ground. The output of the Ratio Box is appropriately marked "OUT" and the low side "COM."

It is important that maximum input voltage does not exceed .35f x the frequency of operation in cps (not to exceed 350V regardless of frequency).

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Switches

The ratio desired is set using the 5 rotary switches and the potentiometer. The first switch controls the most significant digits and covers the range of 0 to 1. The second, third, fourth, and fifth switches cover the ranges of 0 to .1, 0 to .01, 0 to .001, and 0 to .0001, respectively. The potentiometer controlling the sixth decade covers the range of 0 to .00001, providing readability of better than 1 ppm.

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SECTION V

MAINTENANCE

Required Test Equipment

The following is a recommendation for test equipment necessary to calibrate an RB-503 Ratio Box:

Ratio Box Standard - North Atlantic Model RB-504

Null Detector - North Atlantic Phase Angle Voltmeter, 200 Series.

Bridging Transformer - North Atlantic Model T-110.

Calibration and Test Procedure

The precision inductive circuits contained within the RB-503 Ratio Box are extremely stable and capable of retaining the rated accuracy for an indefinite period of time. The accuracy of the RB-503 can be checked using the following procedure.

The circuit shown in Figure 5.1 uses a Phase Angle Voltmeter, such as North Atlantic's 200 Series, as a phase sensitive null detector; a Standard Ratio Box with an accuracy of 1ppm

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(traceable to the National Bureau of Standards); and a bridging transformer to be used to compute the output ratios of the RB-503 and the Ratio Box Standard.

It is important that the bridging transformer used have a common-mode characteristic such that the error introduced by the transformer is no more than 2ppm of full scale excitation voltage.

The RB-503 should be tested at an excitation voltage within its f rating and within the frequency range as outlined in the specifications. The RB-503 should be checked against the Ratio Box Standard for all decades. The null voltage read on the Phase Angle Voltmeter is directly related to the difference in the actual ratio output of the two devices. Relating this null voltage to the line excitation voltage will result in calibration data for the RB-503 (Error (ppm) = $\frac{\text{null error (uv)}}{\text{excitation voltage (volts)}}$). This data will be accurate to within the validity of the test setup - i.e., the accuracy of the Standard Ratio Box and the common-mode error of the bridging transformer. If the magnitude and direction of error of the Standard Ratio Box and bridging transformer are known, a corrected set of data may be generated describing the actual error of the RB-503.

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REPLACEMENT PARTS LIST

NAI PART NO.	DESCRIPTION	NAI PART NO.
D-500063	Switch, 1st Decade	
C-500064	Switch, 2nd and 3rd Decades	
C-500065	Switch, 4th and 5th Decades	
C-500066	Switch, 4th and 5th Decades	2
C-500067	Switch, 1st Decade	1
C-500068	Switch, 2nd and 3rd Decades	2
B-500023-1	Dial Assembly, 0 thru 10, graduated	1
B-500023-2	Dial Assembly, 0 thru 10, ungraduated	5
C-200380	Window	1
B-800568	Rheostat (last digit)	1
	Fuse (Output) 1 amp., Littelfuse #312001 or equal	1
	Fuse (Input) 5 amp., Littelfuse #312005 or equal	1
201792	Ratio Transformer - 1st, 2nd, and 3rd Decades	1
201793	Ratio Transformer - 4th and 5th Decades	1
800941	Knob, GEE-LAR, #J-385 or equal	6

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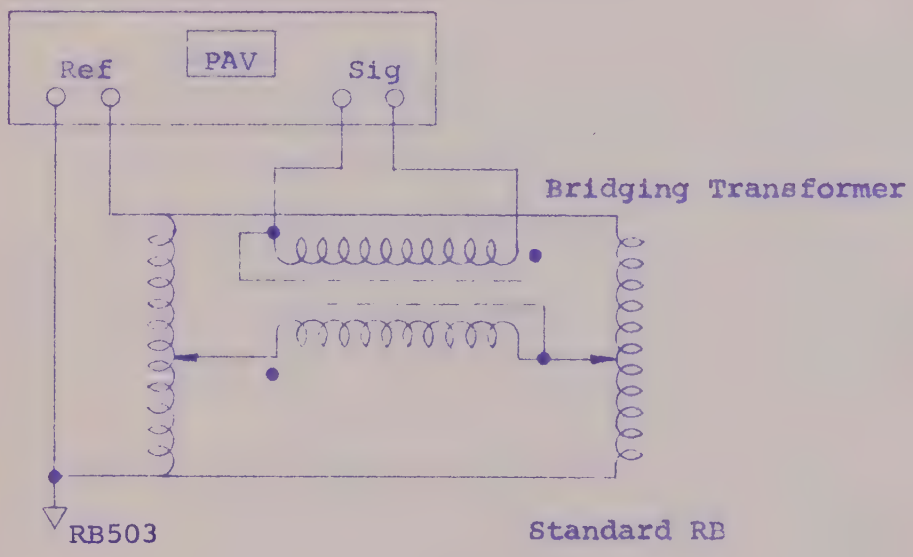

TEST SETUP FOR RB-503

Figure 5.1

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CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

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WARRANTY

North Atlantic Industries, Inc. warrants its products against defects in material and workmanship for one year from the date of the original shipment. Our liability is limited to repairing or replacing products (except fuses and electron tubes) which prove to be defective during the warranty period.

North Atlantic Industries, Inc. is not liable for consequential damages or for any damage or injury to persons or property resulting from the operation or application of any of its equipment.

Warranty is voided if there is evidence that the product has been operated beyond its design range, improperly maintained, or physically mistreated.

In the event of a malfunction in a product under warranty, the purchaser should notify his local Sales Representative or the Sales Department of North Atlantic Industries, Inc. giving full details of the defect and providing the model and serial number of the instrument. Service data or shipping instructions will be forwarded promptly. There is no charge for warranty repair of products, except transportation charges.

North Atlantic Industries, Inc. reserves the right to make changes and improvements in its products without any liability for incorporating such changes or improvements in any products previously sold.

No other warranty expressed or implied is offered other than the foregoing.

Estimates of charges for out of warranty repairs or other service work will be supplied before work begins. Out of warranty repairs will only be made following the receipt of purchaser's authorization of applicable charges.

Claims for Damage in Shipment

The purchaser should inspect and functionally test the product in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

(turn over for Shipping Instructions)

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Shipping

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

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WARRANTY REGISTRATION

Please complete and mail this Warranty Registration Card without delay. Placing this Registration on file with our Service Department will assure that you receive applicable service data as issued. No postage is required.
(Mailed on_____ by_____)

WARRANTY REGISTRATION

Date _____

Please register _____
Model No. _____ Serial No. _____
under the terms of the warranty stated in this Instruction Manual.
Name _____
Title _____ Dept. _____
Company _____
Address _____
City _____ State _____ ZIP _____
Calibration and maintenance responsibility has been assigned to the following person and/or department. Address applicable service data to (if same as above, please state):
Name _____
Title _____ Dept. _____
For our information please indicate:
Condition of instrument on receipt _____
Application _____
Will the instrument be: resold as part of a system? _____
maintained as company equipment? _____

SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

SERVICE INFORMATION REQUEST

Instrument _____
Model No. _____ Serial No. _____
We require the following service information: _____
_____
_____
_____
_____
Name _____ Title _____
Company _____ Dept. _____
Address _____
City _____ State _____ ZIP _____
Phone _____ Ext. _____

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APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter and a power factor meter.

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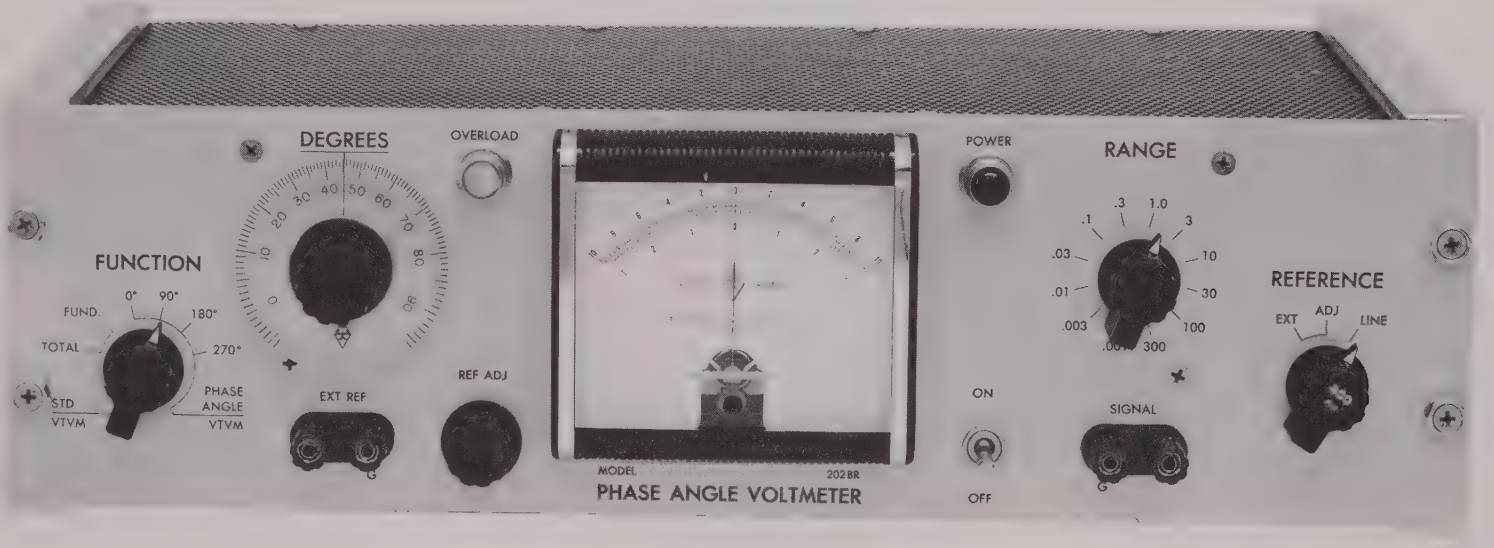


PHASE ANGLE VOLTMETER

TABLE OF CONTENTS

		PAGE
I	Introduction	1
II	General Notes on Grounding Techniques	2
III	Phase Characteristic	4
	1. Response to Harmonics 2. Accurate Phase Measurements	
IV	Phase Angle Measurement Using Phase Shifter	9
V	Measurement of In-Phase and Quadrature Components	10
VI	Measurement of Power Factor and Impedance Angle	10
VII	Measurement of Impedance	11
VIII	Applications	12
	1. Precision Ratiometer	12
	2. Transducer Nulling	13
	3. Synchro Bridge Null Detector	14
	4. Magnetic Amplifier and Thyratron Circuit Alignment	15
	5. Carrier Circuits and Amplifier	15
	6. Transformation Ratio	16
	7. Small Angle Measurements	17

I-INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instruments ability to measure the two basic characteristics of any signal, namely magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure 1.

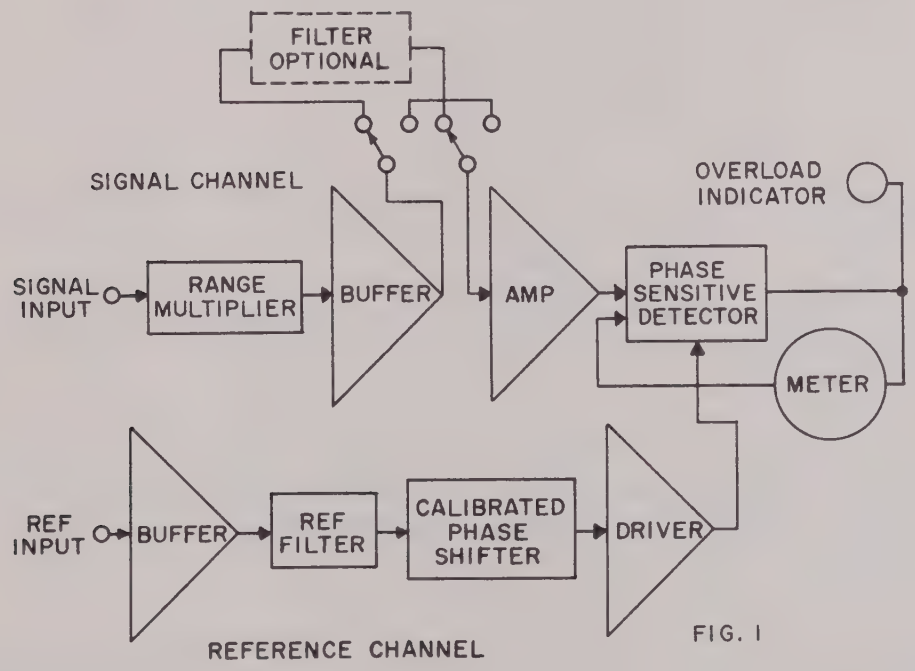


FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an a.c. signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures 5 and 6.

The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II-GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

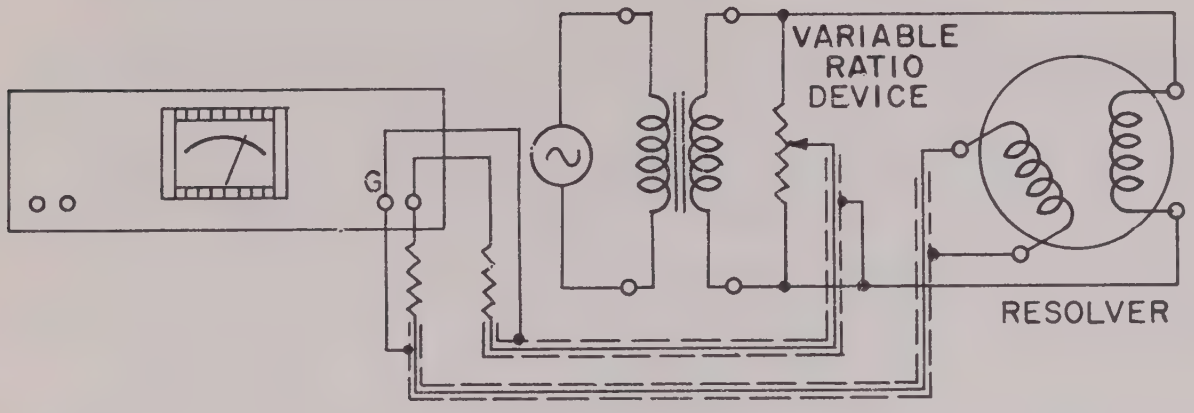
(a) Internal noise
(b) Electrostatic pickup
(c) Inductive pickup
(d) Common Ground Runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

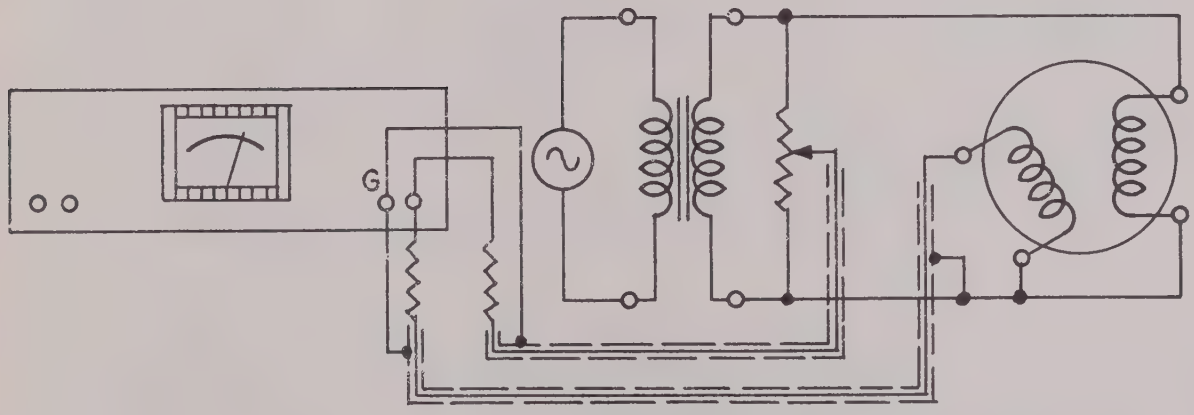
Electrostatic pickup, frequently a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads, one of which is at ground potential. Care must be taken however to avoid loading the signal source by the by the cable capacitance.

Inductive pickup is generally less often encountered than electrostatic pick-up and possibly for that reason methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

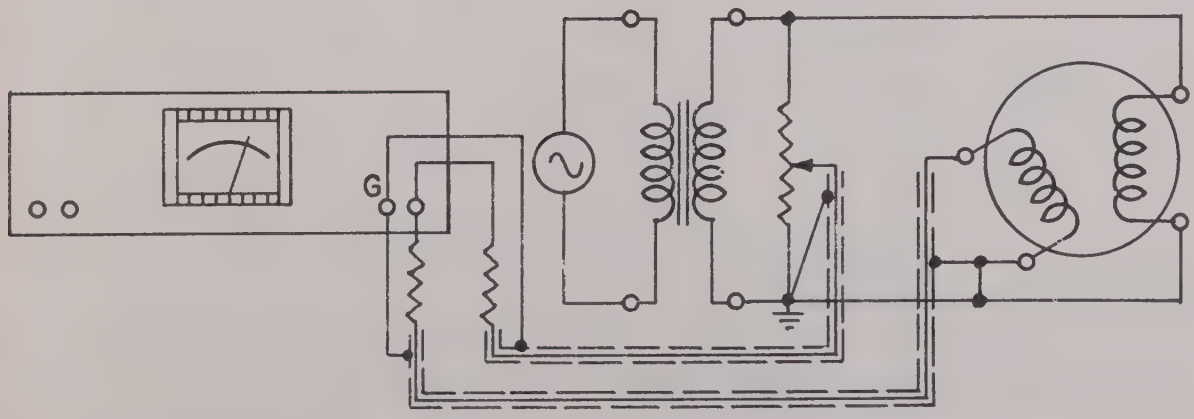
Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that portion of a circuit where a measurement is being made. Fig. 2 shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure 2A is the most advantageous arrangement and is not at all critical to lead runs. Figures 2B and 2C both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure 2 can exist due to chassis contact, line cord ground and reference grounds. All must be considered when setting up the measuring system.



(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

Common Ground Runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure 3 is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure 3 also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

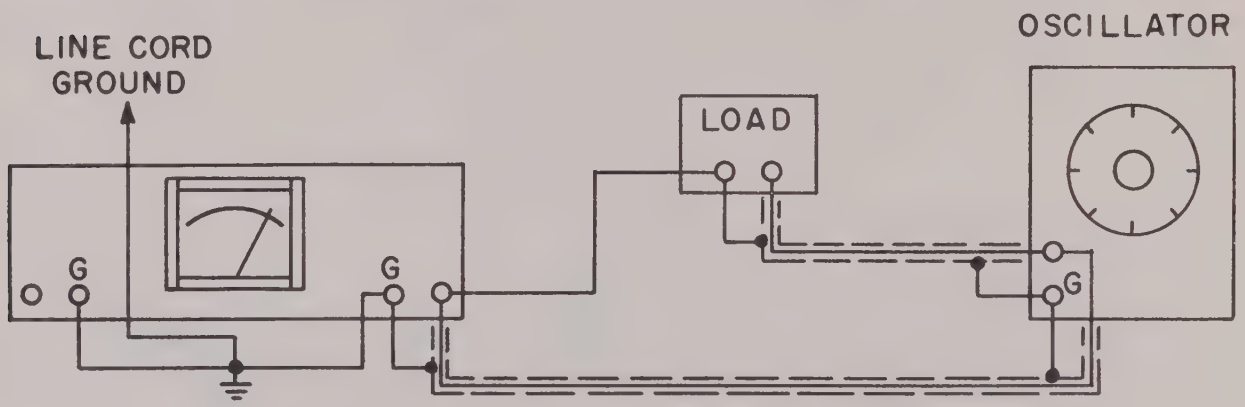


FIG. 3

III-PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter

E_{rms} = rms value of the input sine wave

θ = angle between the reference and signal input (phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

$$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55 db down. Table I shows typical measured responses. The values shown with filters actually are the sum of the column I data and the filter characteristic.

TABLE I

	RESPONSE SIGNAL	
	No Signal Filter	With Signal Filter
FUND (400 cps)	0 db	0 db
2nd Har	-55 db	> -55 db
3rd Har	-9.5 db	> -55 db
4th Har	-55 db	> -55 db
5th Har	-14 db	> -55 db

Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the set-up shown in Figure 4. The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the $\theta = 90$ deg. and the $\theta = 0$ deg. point. Measurement then will be a voltage which can be directly translated into degrees using the curves of Figures 5 and 6.

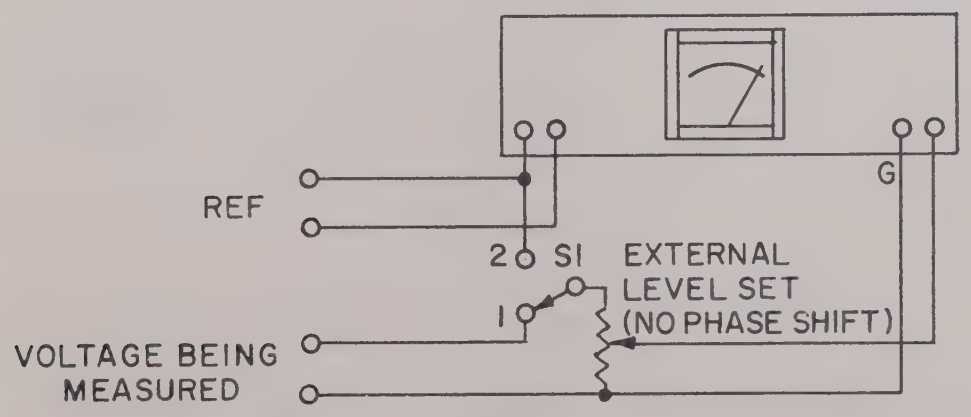


FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (Note: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.

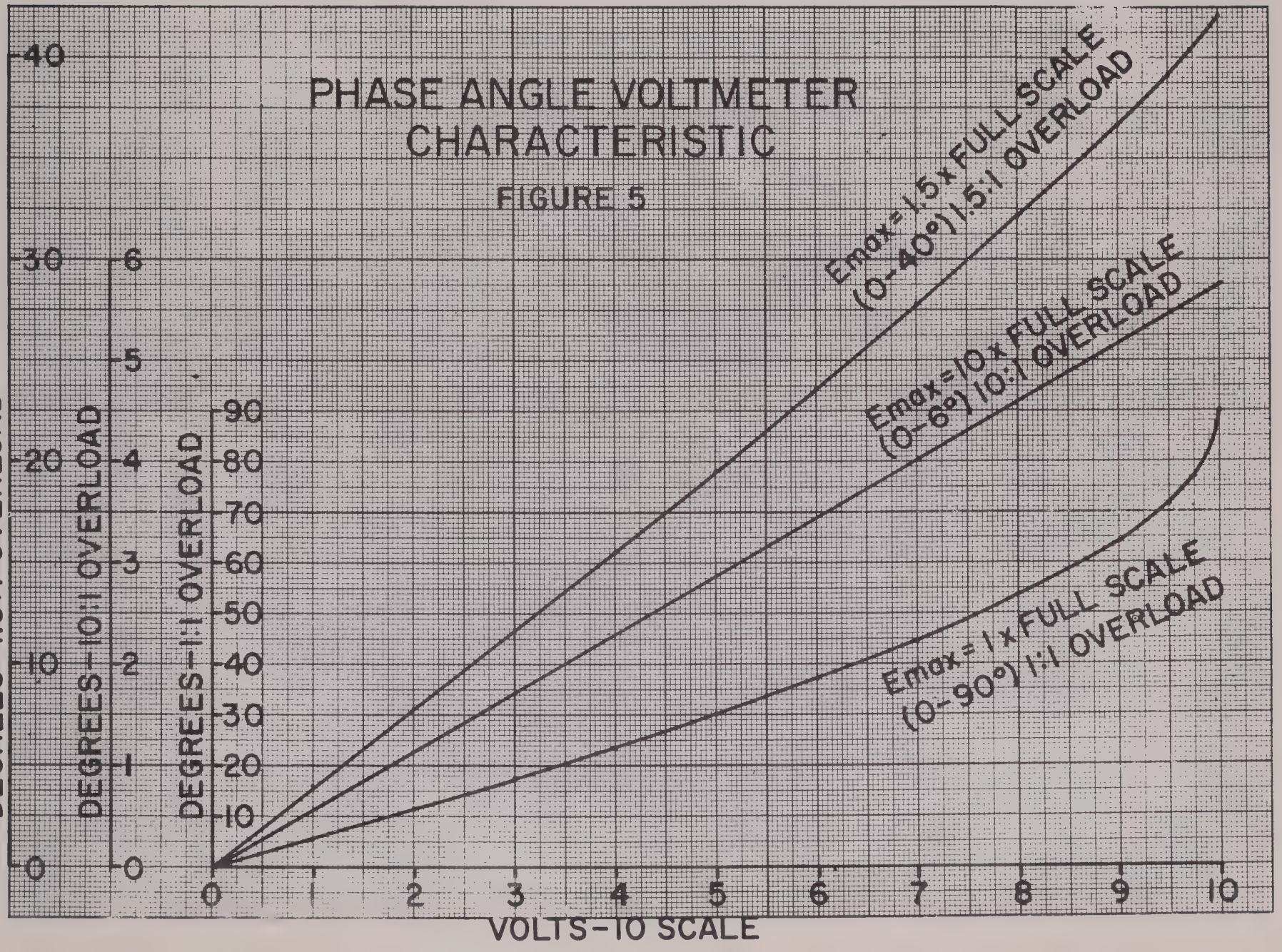
3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection. Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the $\theta = 0$ deg. point or quadrature null point. NOTE: FOR MAXIMUM ACCURACY THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the $\theta = 90$ deg. point. (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure 5 or 6 to read degrees.

Any full scale range in degrees can be used even down to -6°-0-$+6^{\circ}$ depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4 deg.-0- +17.4 deg. Table II summarizes typical set-ups and Figures 5 and 6 show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously this condition is a function of reference level and for that reason a level of twice the red line value is recommended when using this techique.


PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax=1.5x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax=10x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax=1x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE
0
10
20
30
40
0
1
2
3
4
5
6
0
10
20
30
40
50
60
70
80
90
0
1
2
3
4
5
6
7
8
9
10

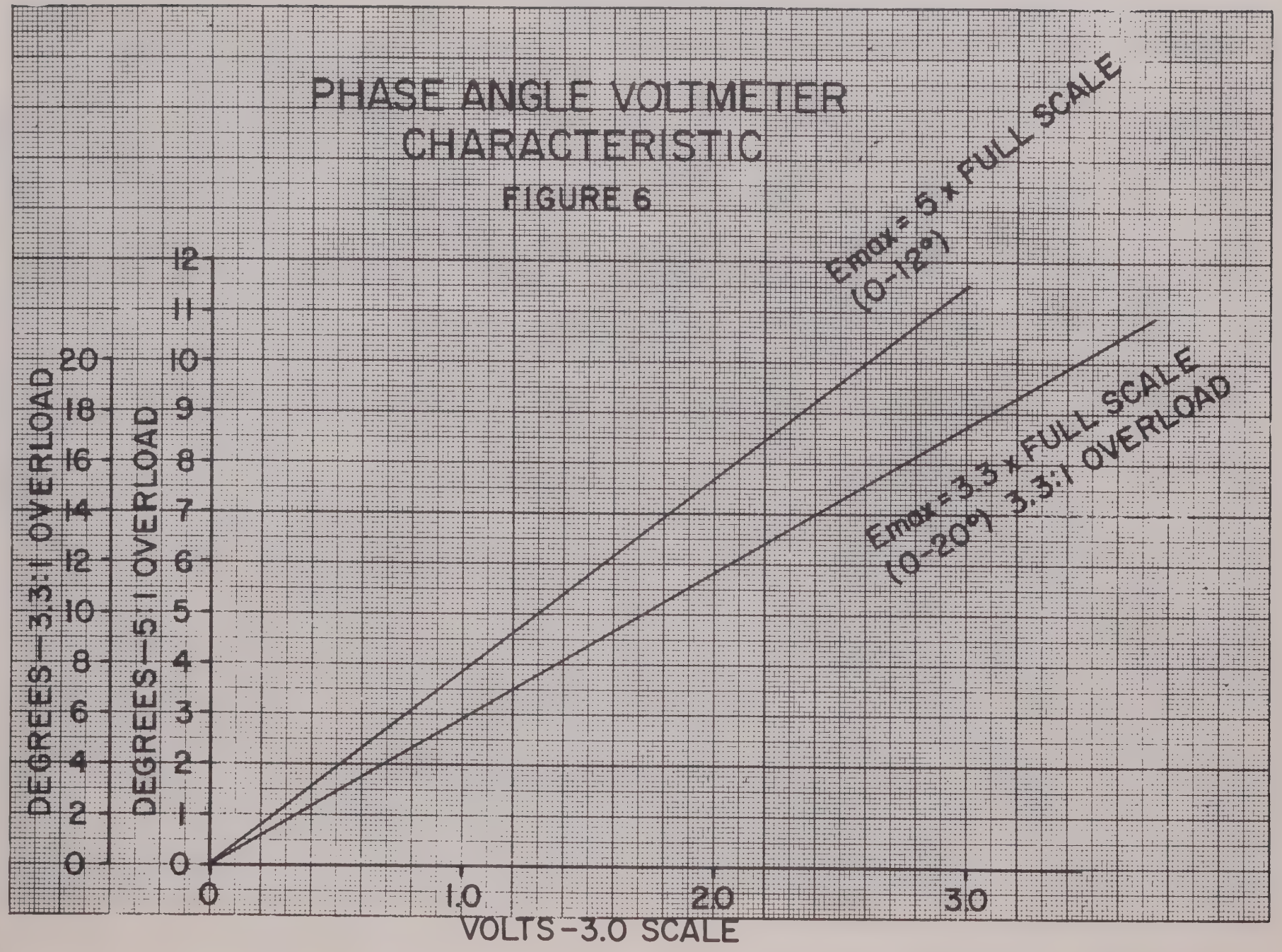

PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES — 5:1 OVERLOAD
DEGREES — 3.3:1 OVERLOAD
0
1
2
3
4
5
6
7
8
9
10
11
12
0
2
4
6
8
10
12
14
16
18
20
0
1.0
2.0
3.0
VOLTS - 3.0 SCALE

TABLE II

Max. Voltage	Scale for meas. deg.	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	$\pm$ 90	2.7 deg.	5
1.0	.3	3.3:1	$\pm$ 19.5	0.6	6
1.0	.1	10:1*	$\pm$ 5.7	.2*	5
1.5	1.0	1.5:1	$\pm$ 41.8	1.3	5
1.5	.3	5:1	$\pm$ 11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV-PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built in calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V-MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

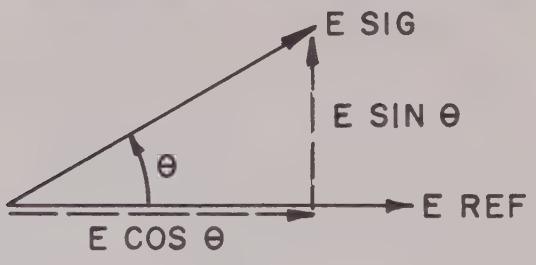


FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure 7 as:

In-phase component = E cos θ

Quadrature Component = E sin θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin θ. For the greatest accuracy in this type of measurement the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI-MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This measurement is conveniently accomplished by means of the set-up shown in Figure 8. The angle is measured as previously discussed.

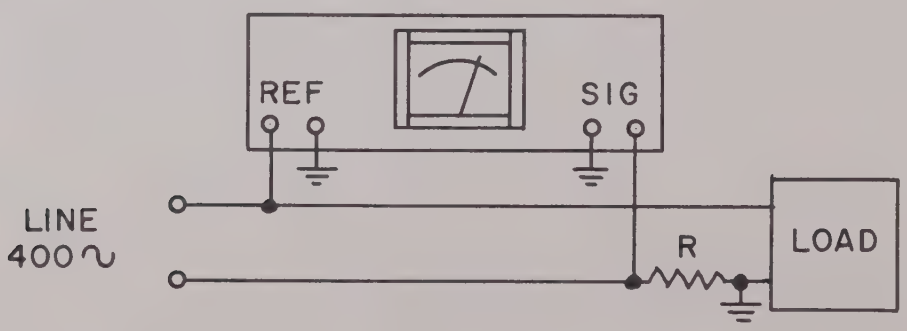


FIG. 8

VII-IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure 9 illustrates the manner in which the measurements can be made.

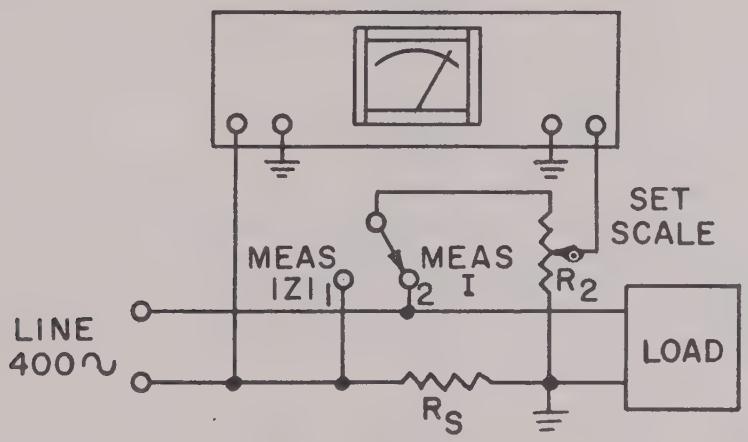


FIG. 9

Using Table III as a guide, a precision (≠ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale volts on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE

Load Impedance = 470K

Rs = 1K

E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1 Volt Equals	Current Factor
10K	10K	1/volts
1K	1K	"
100 ohms	100 ohms	"
10 ohms	10 ohms	"
1 ohm	1 ohm	"

Measurement of A.C. Resistance and Reactance

By using the circuit of Figure 9 the real and imaginary components of the impedance can also be measured directly by using the current as a referency and measuring the in-phase and quadrature components of the signal measured with the switch in position 2. The in-phase component will be the A.C. Resistance and the quadrature component will be the reactance with the sign determined as positive for a right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII-APPLICATIONS

Precision Ratiometer

In many analogue computer systems the process of multiplication, division, addition and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure 10 permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

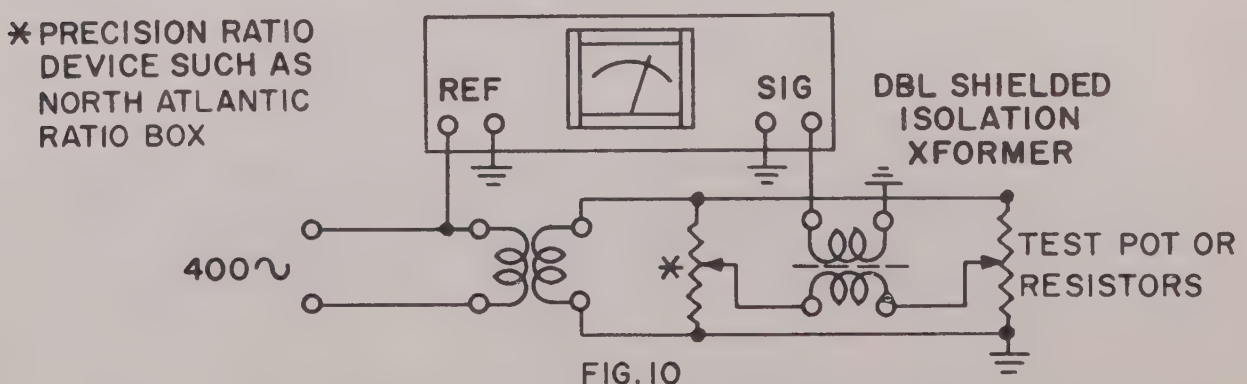


FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance transformer such as a North Atlantic T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

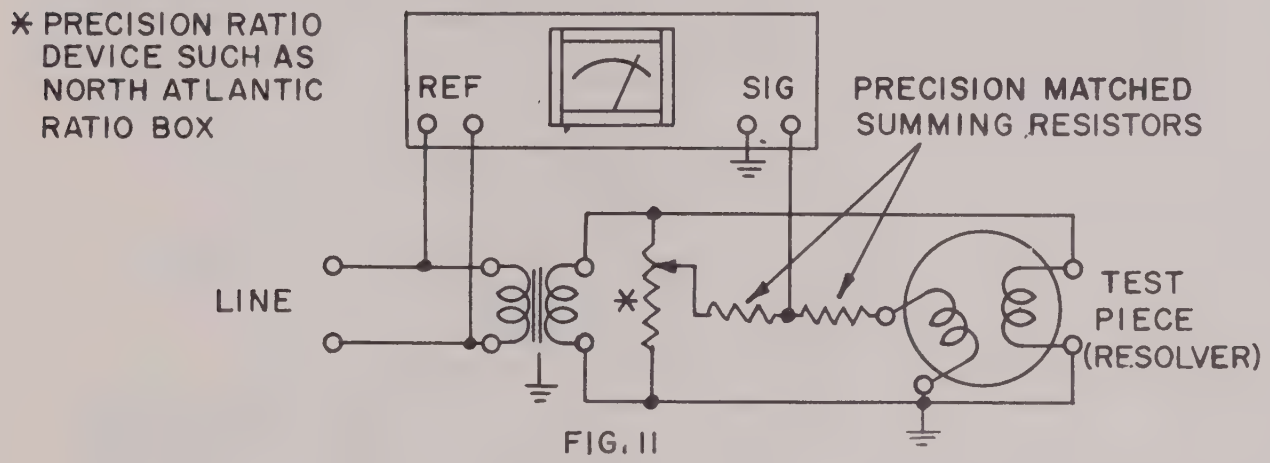


FIG. 11

Transducer Nulling

Applications involving transducers such as differential transformers or E-Coil pickoffs are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure 12 shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

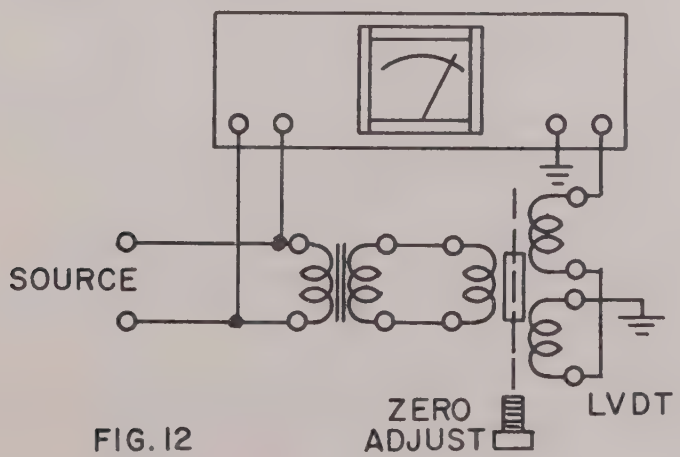


FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure 13 is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible precision nulls unobtainable by conventional instrumentation.

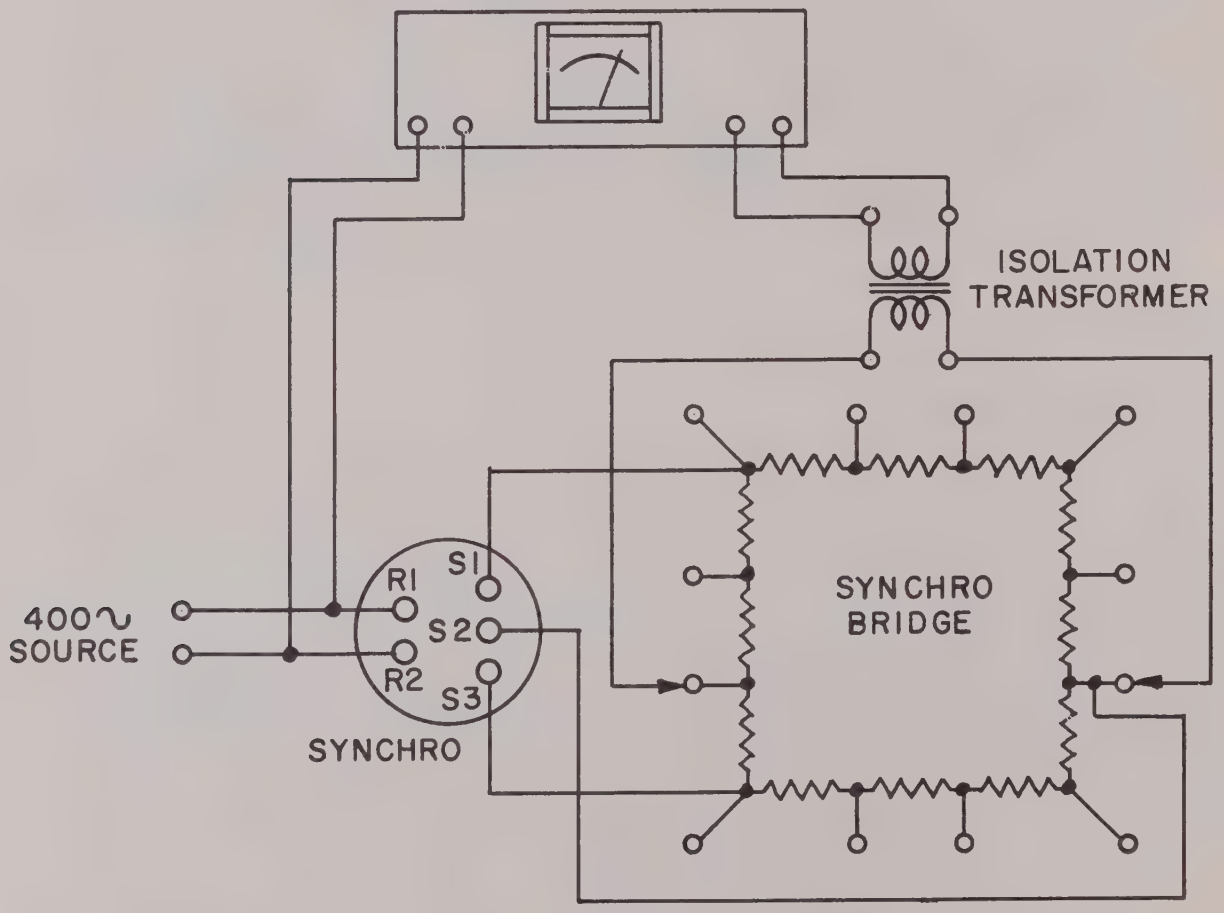


FIG. 13

Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped wave forms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure 14, the task of alignment for maximum torque or output is straight forward since the meter reading is equivalent to motor output.

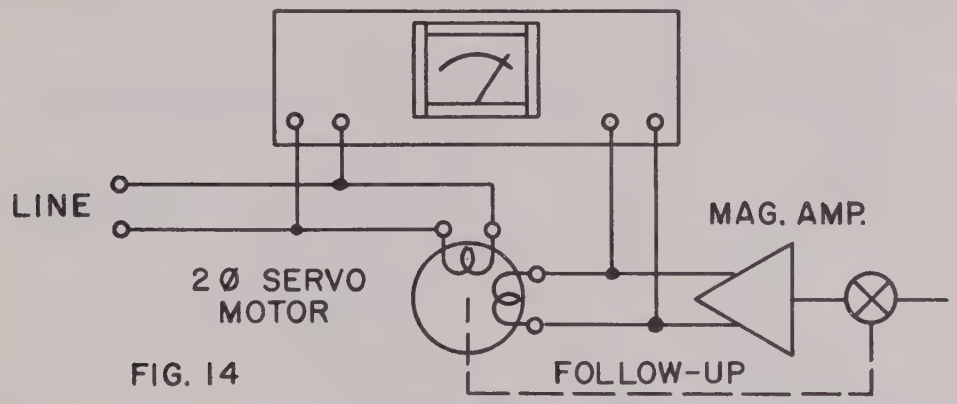


FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc. must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure 15 is a test set-up used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

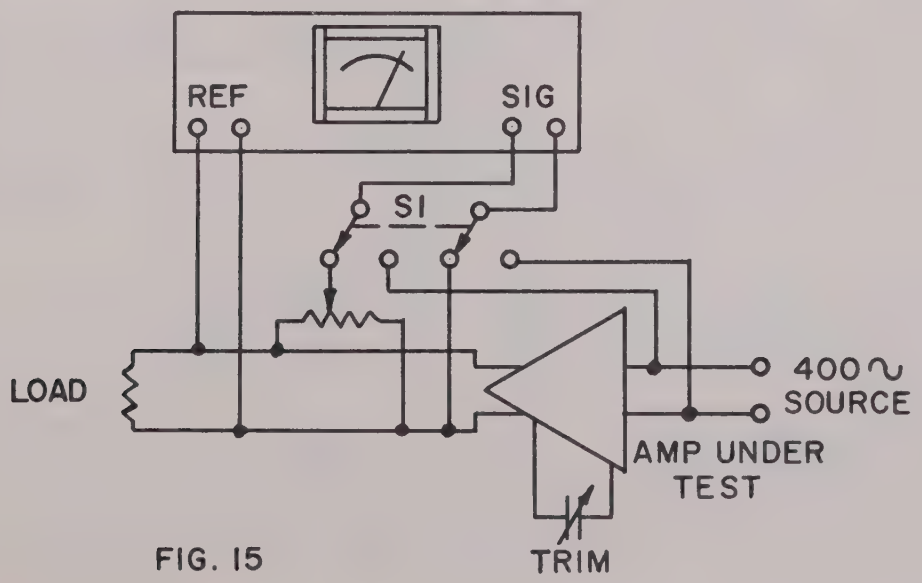


FIG. 15

TRANSFORMATION RATIO

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure 16 (a) and 16 (b).

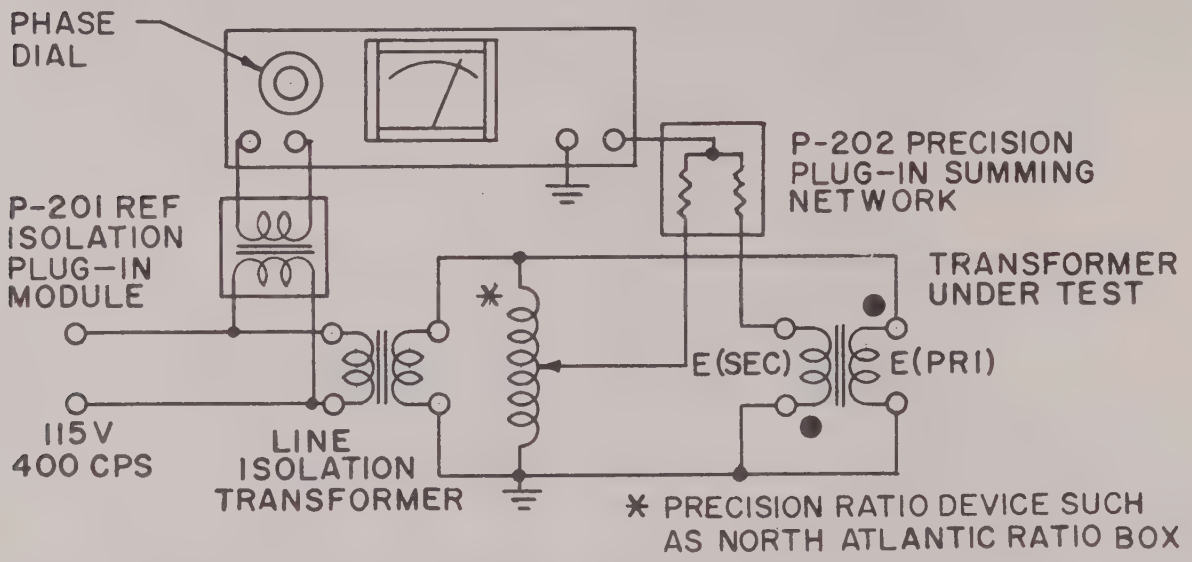


FIGURE 16(a)

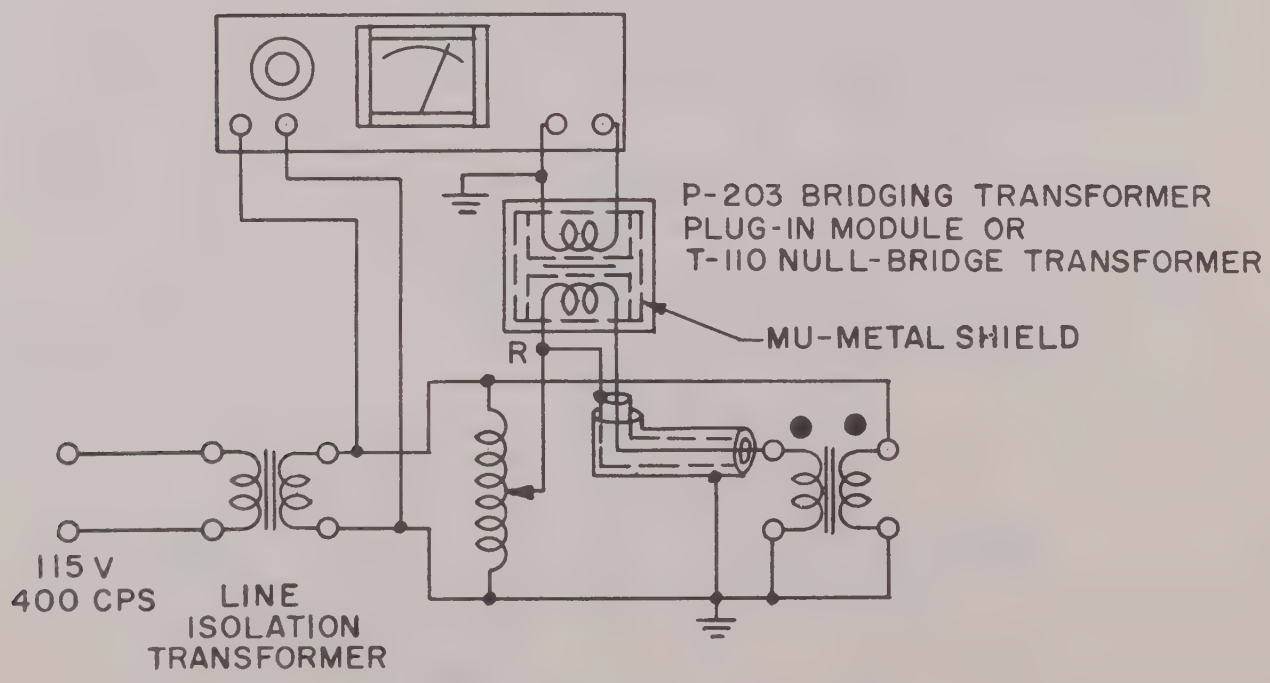


FIGURE 16(b)

I. SUMMING NETWORK TECHNIQUE

In Figure 16 (a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test set up a line isolation transformer is utilized so as to avoid grounding one side of the line. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure 16 (a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure 16 (b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common mode rejection and low input capacitance would suffice.

Measurement errors in Figure 16 (b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the figure.

Common mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each set up must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both set-ups require that the phase dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc.. This is conveniently done by stepping the ratio device and adjusting the phase dial to produce zero output when the function selector is in the 90° position. Operation will then be correct when the function selector is returned to the 0° position.

Small Angle Measurements

Small angle measurements to better than .01° can also be made using the set ups of Figure 16. The process consists of making the in-phase null, described in the foregoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}}$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

Measured quadrature = 30.0 millivolts

Secondary voltage = 30 volts

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\equiv 0.001 \times 57.3 = .057 \text{ degrees}$$

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